

- 1 -

### D e s c r i p t i o n :

#### An elongated stopper device

The invention relates to an elongated stopper device for flow control of molten metal, i.e. for controlling the flow of molten metal from a metallurgical vessel, such as a tundish.

It is well known in steel casting to employ a one-piece refractory stopper rod, which is moved vertically by the use of a lifting mechanism in order to vary the cross-sectional area of an outlet opening of the corresponding metallurgical vessel.

Those stopper rods have also been used to introduce an inert gas, such as argon, into the molten steel for removing non-metallic inclusions from the molten metal.

In all cases the stopper device must withstand hours submerged in molten metal. It must also be capable of enduring the harsh thermal shock encountered on the start-up of casting and any mechanical forces imposed to it.

Insofar many attempts have been made to improve the mechanical and thermal properties of such a stopper device and to improve its behaviour during use.

EP 0 358 535 B2 discloses a one-piece refractory stopper rod adapted to a lifting mechanism, comprising an elongated stopper rod body of a refractory material, which body being provided with a bore hole, having a longitudinal axis and extending from an upper surface of said body downwardly. Within said axial bore hole a metal bushing is inserted to threadably receive a threaded part of a metal rod, inserted in said refractory body for attachment to a corresponding lifting mechanism.

One problem with such device is the anchorage of said metal bushing with the refractory material of the body and the requirement to avoid differential stresses between the ceramic body and the metal bushing insert, which can cause mechanical breakage of the ceramic material during service operation.

According to DE 198 23 990 C2 a stopper device is disclosed, providing an upper part of the bore hole embodying a ceramic insert. This insert provides an inner thread, corresponding to an outer thread of a corresponding metal rod threadably fixed within said insert after insertion of the rod into said threaded insert. Whilst the use of two ceramic materials reduces the risk of differential stresses between the body material and the holding insert problems remain associated with the difficulty in maintaining an accurate threadform in a high strength ceramic material at an acceptable cost.

It is therefore an object of the present invention to provide an elongated stopper device for flow control of a molten metal from a vessel, containing molten metal, which is easy to produce and provides simple fixing means for attachment of a corresponding metal rod within a corresponding refractory ceramic body.

It has now been found that such attachment of the metal rod within a corresponding bore hole of the refractory ceramic body may be achieved with much simpler means than a cylindrical metal bushing or an elongated cylindrical ceramic insert, namely by at least one anchor such as a sheet like part of a different material (compared with the material of the body), whereby said anchor is fixed within said body between the upper surface of said body and a lower end of the corresponding bore hole and protrudes radially into said bore hole with its main surfaces running predominantly perpendicular to the longitudinal axis of the bore hole within the upper part of the body.

Contrary to prior art constructions, which disclose fixing means for the metallic rod, said known fixing means all extending along a significant length of the longitudinal axis of the elongated refractory body, the invention provides a fixing means arranged predominantly perpendicular to the longitudinal axis of said body and/or said bore hole respectively and at a specific position along the length of the bore within said body. Insofar these fixing means are much smaller than a bushing, i.e. much less different material is introduced into the ceramic body and much less thermal and mechanical stresses between fixing means (anchor) and ceramic body are to be expected.

In other words: The said anchor is arranged at a specific height of said elongated stopper device at a distance to its upper surface and at a distance to its lower end. Typically it is arranged at a place between 10 and 40 % of the total length of the stopper device, calculated from the upper end of the refractory body, which may be 5-25 cm, typically about 10 cm from the upper end.

Obviously such a generally radial fixing means presents a significantly reduced axial length than any insert or bushing extending along the longitudinal axis of a stopper. Any mechanical stresses generated in the ceramic body by the longitudinal thermal expansion effects arising from said generally radial fixing means are therefore much lower than those generated with prior art constructions.

Further it may easily be fixed within the ceramic refractory surroundings (refractory body material), for example during isostatic pressing of said stopper device.

The manufacturing may be done as follows: The aforementioned anchor(s), for example sheet like part(s) is (are) placed with their end portion located into corresponding slits of a suitable mandrel (core rod). A rubber outer mould is placed over the mandrel assembly and a refractory ceramic material is filled into the cylindrical space between the mandrel and mould. Thereafter the mould containing the refractory material, including the fixing means, is isostatically pressed. The outer mould is then removed and the mandrel, made of at least two longitudinally running parts, is removed from the compacted product leaving the outer portion(s) of the anchor(s) (sheet like parts) firmly embedded in the ceramic body with their inner extremity(ies) projecting into predetermined position(s) within the ceramic bore.

During said manufacturing a sealing member may further be placed within said mould, as will be described later.

In its most general embodiment the invention relates to an elongated stopper device for flow-control of molten metal from a vessel, containing molten metal, said device comprising:

- a body made of a refractory ceramic material,
- a bore hole, having a longitudinal axis and extending from an upper surface of said body downwardly,
- said bore hole being equipped along its length with at least one anchor of a different material, fixed within said body between the upper surface of said body and a lower end of said bore hole and projection radially into said bore hole with its main surfaces running predominantly perpendicular to the longitudinal axis of the bore hole,
- said anchor being adapted to receive and fix one threaded end of a metal rod, inserted into said bore hole.

According to an embodiment said metal rod has an at least partially threaded section at its inserted end. This threaded section serves, together with the anchor (fixing means) for attachment of said metal rod within said bore hole of said refractory body.

It will be sufficient to achieve said attachment by providing just one anchor, like a sheet like part, projecting radially into said bore hole. During insertion of the rod into the bore hole the threaded section of the rod will run along said fixing part and provide the necessary attachment of said rod within said body.

Obviously this fixing (anchoring) means should best have a certain circumferential length. It may extend over  $20^\circ$  to  $\leq 360^\circ$  of the inner wall of said bore hole or even a bit more.

Especially in cases where it extends over more than  $20^\circ$  it will be advantageous to arrange said sheet like part with a certain declination (descending gradient or slope) with respect to the longitudinal axis of the bore hole, but not necessary to achieve the desired locking.

This is especially true if the anchor (sheet like part) is more or less ring shaped, i.e. running in the circumferential direction around the inner bore hole surface for more than  $180^\circ$ , especially more than  $270^\circ$  and it must be sloped when this part has a length of more than  $360^\circ$ . A snap ring design is one further possibility.

While said anchor may be designed as a ring, for example with a circumferential length between  $270^\circ$  and  $\leq 360^\circ$  or up to  $450^\circ$  or  $300^\circ$  to  $400^\circ$  it is also possible to prepare said fixing means by at least two anchors, each designed like a ring section and arranged at a distance to each other along an imaginary helical line. A further embodiment provides fixing means made of three anchors, each designed like a ring section and arranged at equal distances to each other along an imaginary helical line. Even two or three radially arranged pins, spaced to each other, may provide the necessary anchoring means for securing and holding the rod within the body. The anchor(s) may also be arranged along a plane, perpendicular to the longitudinal axis of the rod.

It becomes clear from the explanation above that a one piece fixing means is the most convenient way for an easy production of said stopper device.

Said fixing means may be made of any material, different from the material of the refractory body and strong enough to threadably receive the threaded part of the corresponding metal rod. For example the fixing means may be made of metal or special ceramics like silicon nitride, zirconia or alumina.

As explained above a sealing member may be arranged along said bore hole and best adjacent to said fixing means.

This improves the tightness between the ceramic body and the metal rod, especially in cases where said stopper rod is used for introducing a gas into a metallurgical melt.

A corresponding sealing member (gasket) may be placed upon a corresponding annular sealing surface, provided at a certain height of the bore hole. This construction is further disclosed in EP 1 135 227 B1, the disclosure of which is insofar referred to here.

Said sealing means may also be arranged along a circumferential wall of said bore hole below or above said fixing part and extending radially into said bore hole and longitudinally along a certain length of said bore hole and adapted to receive said rod in a threadably manner.

Insofar as in this description reference is made to "above", "upper", "lower", "downwardly", etc it is referred to the typical use of such stopper rod, running predominantly vertical.

As described above a sheet like part used for attachment of the corresponding rod is arranged along a defined longitudinal position of the body. Therefore, when introducing the rod, the corresponding outer thread of said rod will protrude downwardly over said fixing means. This protruding part of the threaded rod section is now used to provide an effective sealing as it will be engraved into said gasket. The material of the gasket, withstanding high temperatures, thereby penetrates into the threads and causes a very effective

sealing and tightness over the corresponding lengths of said sealing and said rod respectively.

Said sealing member may have a cylindrical shape. It should protrude into the bore hole.

That part of the bore hole, receiving the sealing member, may be conically designed with its smaller part at its lower end.

The rod may then have a smaller width at its part adjacent to said sealing member compared with its part on top.

The sealing member may be made of any material withstanding high temperatures as may be present during use of stopper device. Graphite is one of those materials. A possible material is a compressed graphite material with a purity  $> 95$  weight-% carbon and a density of approximately  $1,4 \text{ g/cm}^3$ . The seal may have the form of a preformed component which can be either inserted into the stopper body immediately prior to the installation of the steel support rod or co-formed with the ceramic body of the stopper rod during the production process.

Alternatively the seal may be created during the fabrication process of the stopper by compression of a graphite element comprising either exfoliated graphite powder or a coil of a graphite foil, placed around the forming tool (mould) and then surrounded by the ceramic body material of the stopper during the mould filling process.

It seems clear from the description above that if said stopper device is used for introducing gas the corresponding rod will be equipped with an axial bore through which the gas is fed. The corresponding bore hole of the body will then be provided with at least one opening at its lower end.

Further details of the invention will be described in the subclaims and the other application documents.

The invention will now be described with respect to one embodiment which in no way limits the scope of the claimed stopper device.

The only figure shows schematically an upper part of a stopper device in a partly longitudinal cross sectional view.

The stopper device comprises an elongated refractory body 10 with a central bore hole 12, positioned coaxially with respect to body 10 and adapted to receive fixedly a metal rod 14 for its attachment to a (non-shown) lifting mechanism.

The bore hole 12 is of more or less cylindrical shape and is running from an upper surface 10u of the body 10 downwardly (arrow D) and terminating in a (non-shown) opening at a lower end of said body 10.

At a distance d from upper surface 10u a sheet like metal ring 16 is integrated in the refractory material of body 10. Said ring projects radially into said bore hole 12. Main surfaces (upper surface 16u; lower surface 16l) are running predominantly perpendicular to a longitudinal axis A of said bore hole 12.

In the figure said flat ring 16 is arranged such that it provides an angle  $\alpha$  of ca. 3 degrees to a horizontal plane (perpendicular to longitudinal axis A). This angle may be adapted to match the pitch of the threadform on the metal rod 14. Said ring 16 is not closed but slit and encircles an angle of about 330°. Free ends of said ring are offset in the longitudinal direction of bore hole 12.

This sheet like ring 16, serving as a fixing means for said rod 14, which will be described later, has been co-pressed with body 10. It protrudes (projects) into bore hole 12 over a certain width so as to threadably receive an outer thread 14t (symbolized by dots) of a lower part 14l of metal rod 14, which may have a central, longitudinal through passage 14c (symbolized by lines).

During assembling said metal rod 14 is introduced into bore hole 12, thereby turned, so that the outer thread 14t of rod 14 engages the protruding part 16p of ring 16.

Rod 14 is then further introduced into bore hole 12 (downwardly, arrow D) and then engages a cylindrical graphite gasket 18, arranged over a length L in front of an inner wall 12w of bore hole 12.



During said further introduction of rod 14 into bore hole 12 the gasket material penetrates into spaces of thread 14t, thereby providing intimate sealing between body 10 and rod 14 all over length L.

According to the figure the final position of rod 14 within bore hole 12 is characterized by a small projection of threaded end 14e past the end of sealing member 18. Alternatively the threaded rod could finish within the length of the sealing element.

Upper surface 10u of body 10 butts on blocking means 20, 22 located fixedly on metal rod 14 so that rod 14 may not lengthen opposite to arrow D. Blocking means 20, 22 have a nut-like shape and are prepared with inner threads, corresponding to thread 14t of rod 14.

The limited size of said sheet like fixing means (slit ring 16) and its mostly horizontal (radial) arrangement with respect to the elongated stopper design guarantees safe fixation of rod 14 in bore hole 12 even when under high thermal load said metallic fixing means and said metallic rod will expand equally in a radial direction, with little or no differential expansion in the axial direction.

Together with the downwardly following sealing gasket the described design leads to an improved stopper device which may be used for different purposes, i.a. for feeding a gas along channel 14c and bore hole 12 into a metal melt. The intimate contact between gasket 18 and outer thread 14t of rod 14 are further responsible for the radial compression of the sealing element and improved tightness of said device. The expansion of the metallic rod at service temperature serves to further increase the sealing efficiency by maintaining compressive forces on the seal.

In the longitudinal direction the fixing means should be as small as possible. It may have a "thickness" of  $\leq 5\text{mm}$ ,  $\leq 3\text{mm}$ ,  $\leq 2\text{mm}$  or even  $\leq 1\text{mm}$ , while the "length" (L) of said sealing means may be  $\geq 10\text{ mm}$ ,  $\geq 20\text{mm}$ ,  $\geq 30\text{mm}$  or  $\geq 40\text{ mm}$ .

The invention includes embodiments with two or more fixing means at different positions along the longitudinal axis of the elongated stopper rod, i.e. the respective fixing means have a distance to each other (in the longitudinal direction of the bore hole). The distance may be in the range of a few cm or more. These distinct fixing means may coact with one or more outer threads of the metallic rod.